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XP 1002: Core impurity density and P_{rad} reduction using divertor condition modifications

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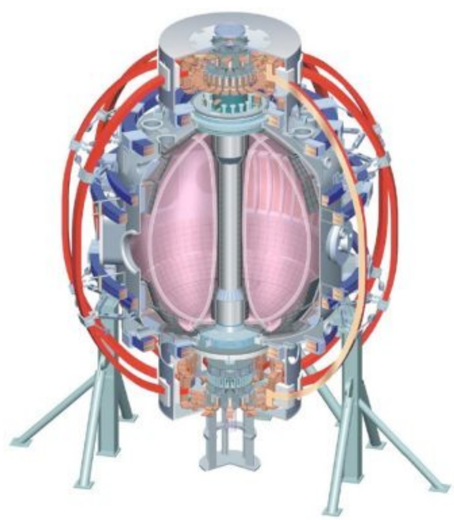

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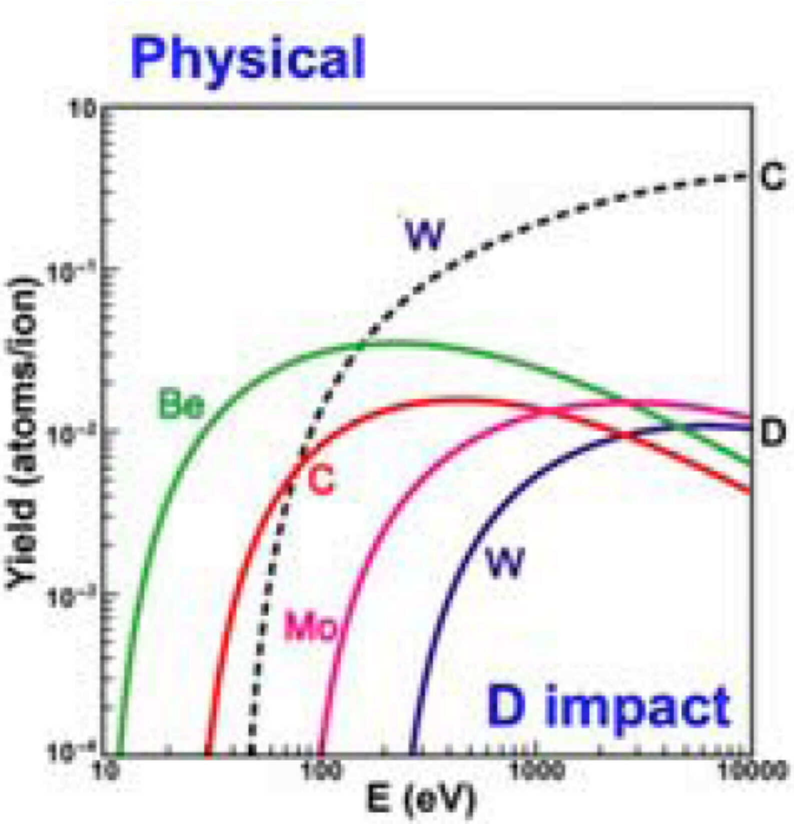
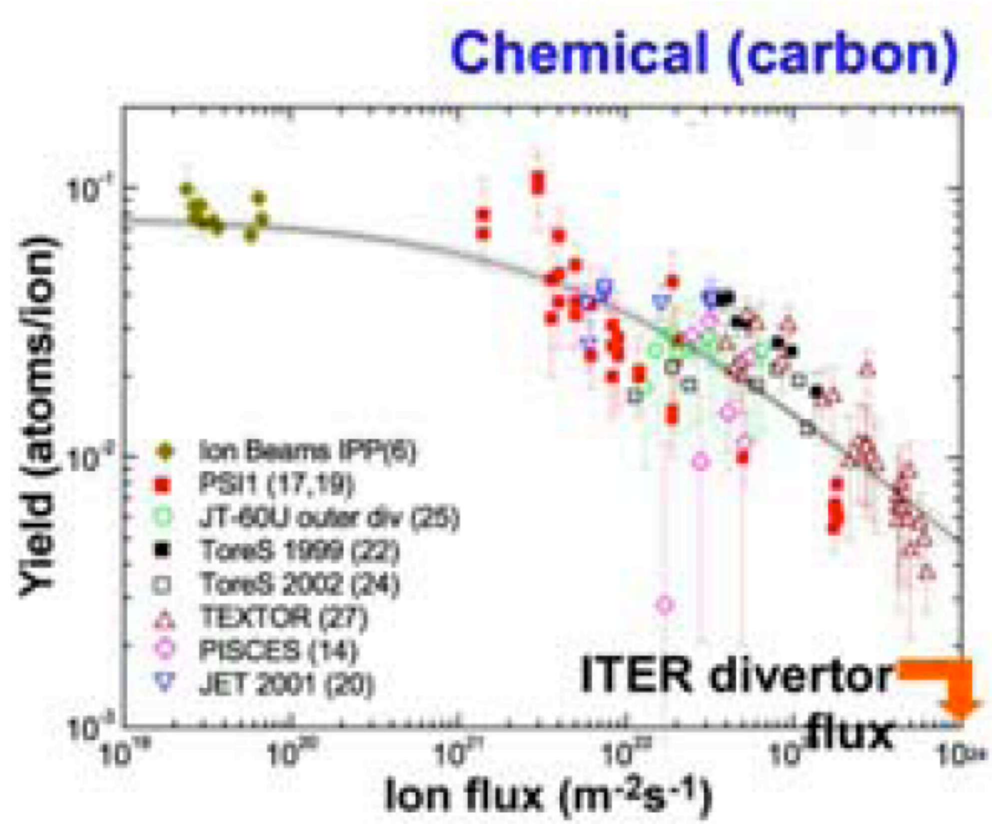
Impurity sources are due mainly to physical and chemical sputtering from deuterons and impurities

- Where is the dominant influx – divertor or main chamber?
- Sputtering due to ELMs is highly non-linear





SOL transport carries ionized impurities to the confined plasma

- Balance between anomalous (turbulent) cross-field transport and classical parallel transport
- Parallel transport dominated by collisional processes: frictional drag and ion temperature gradient forces

  (Stangeby 2000)

$$F_{\|} = -\frac{1}{n_z}\frac{dp_z}{dx} + m_z\frac{v_i - v_z}{\tau_x} + ZeE + \alpha_e\frac{(kT_e)}{dx} + \beta_i\frac{(kT_i)}{dx} + o()$$

Target: ← ← ← → →

- 2D fluid codes include most of the physics
  - Classical Braginskii parallel transport, anomalous radial transport
  - E x B and grad B drifts
  - sputtering models

SOL and divertor conditions are significantly modified due to lithium coatings

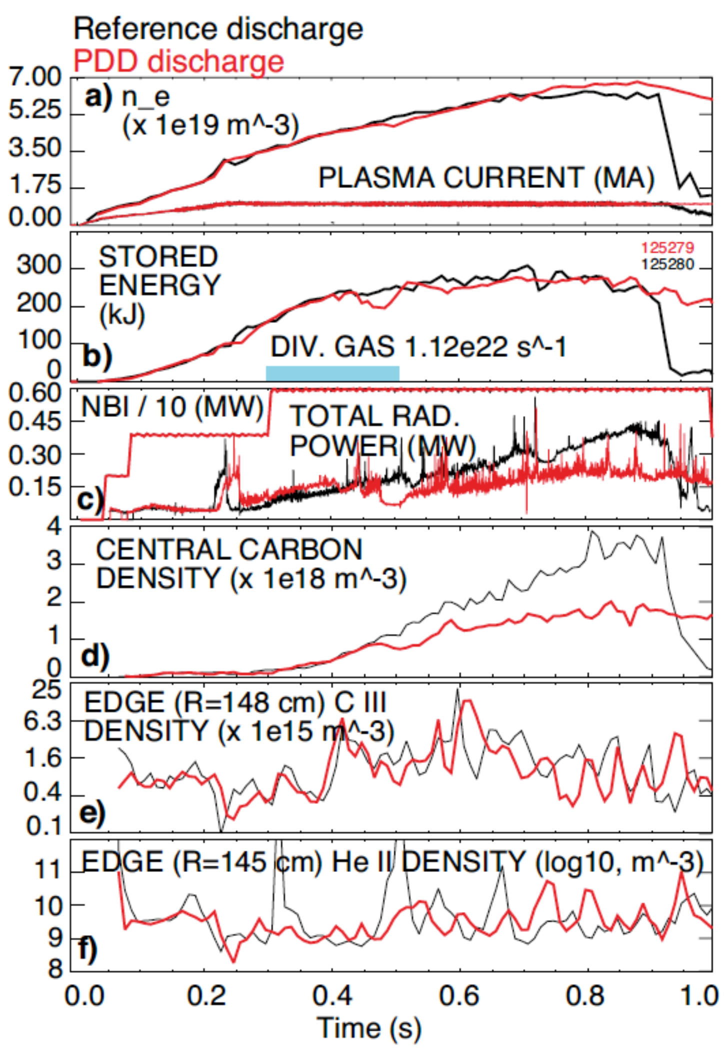
- Evaporative lithium coatings on carbon PFCs modify divertor and SOL sources
  - Lower divertor, upper divertor and inner wall recycling was reduced by up to 50 %
  - Local recycling coefficients reduced on inner wall and far SOL, remained similar in the outer strike point region
  - Lower divertor carbon source from physical sputtering did not increase
  - Divertor lithium influx increased, however, lithium was retained in divertor

- SOL transport regime changes from high-recycling to sheath-limited
  - Apparently small parallel T_e gradient
  - Detached inner divertor re-attached, X-point MARFEs disappeared

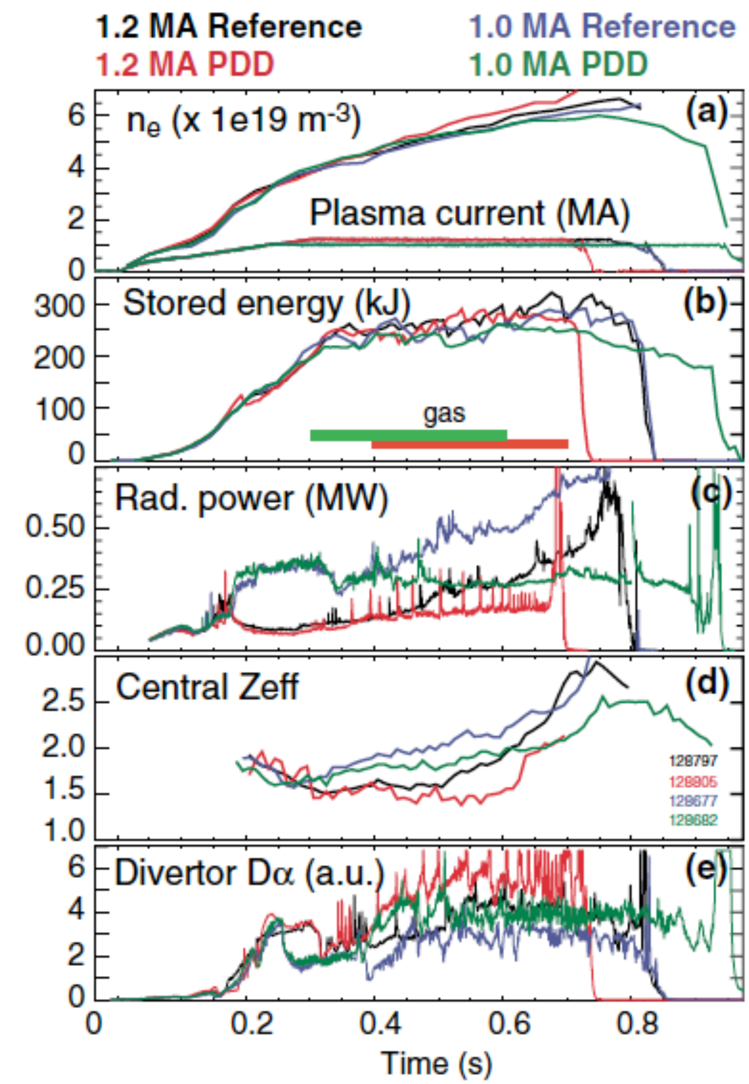
- Pedestal and core confinement improvement leads to
  - Reduction of ion inventory (density) by up to 50 % due to surface pumping
  - Effective screening of lithium from core plasma
  - **Carbon and high-*Z* impurity accumulation**
    - P_{rad} increases in the core while P_{SOL} reduced

Significant core n_C and P_{rad} reduction observed in divertor heat flux mitigation experiments (w/o lithium)

Phys. Plasmas **16**, 022501 (2009)

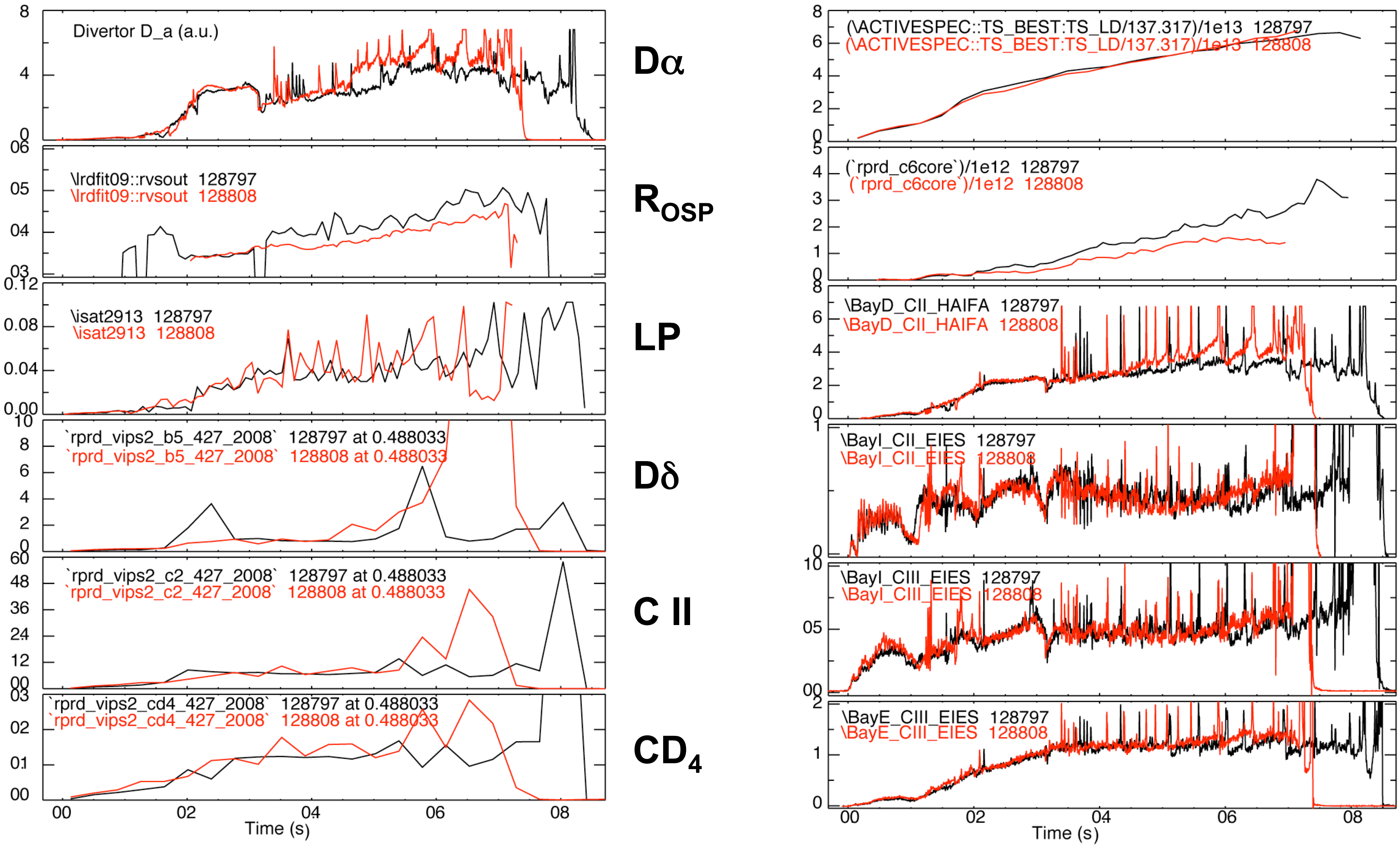


Nucl. Fusion **49** (2009) 095025



Due to more frequent ELMs? or source reduction?

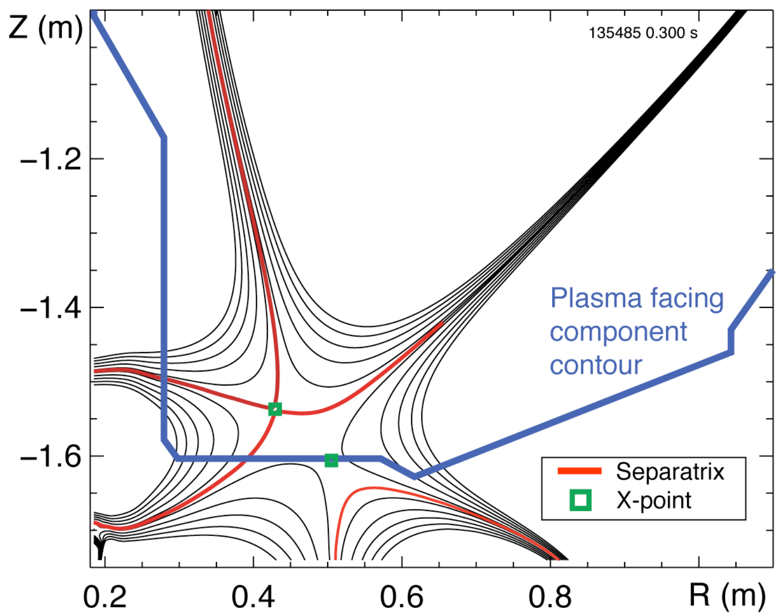
Divertor carbon source evaluation in PDD discharges was inconclusive

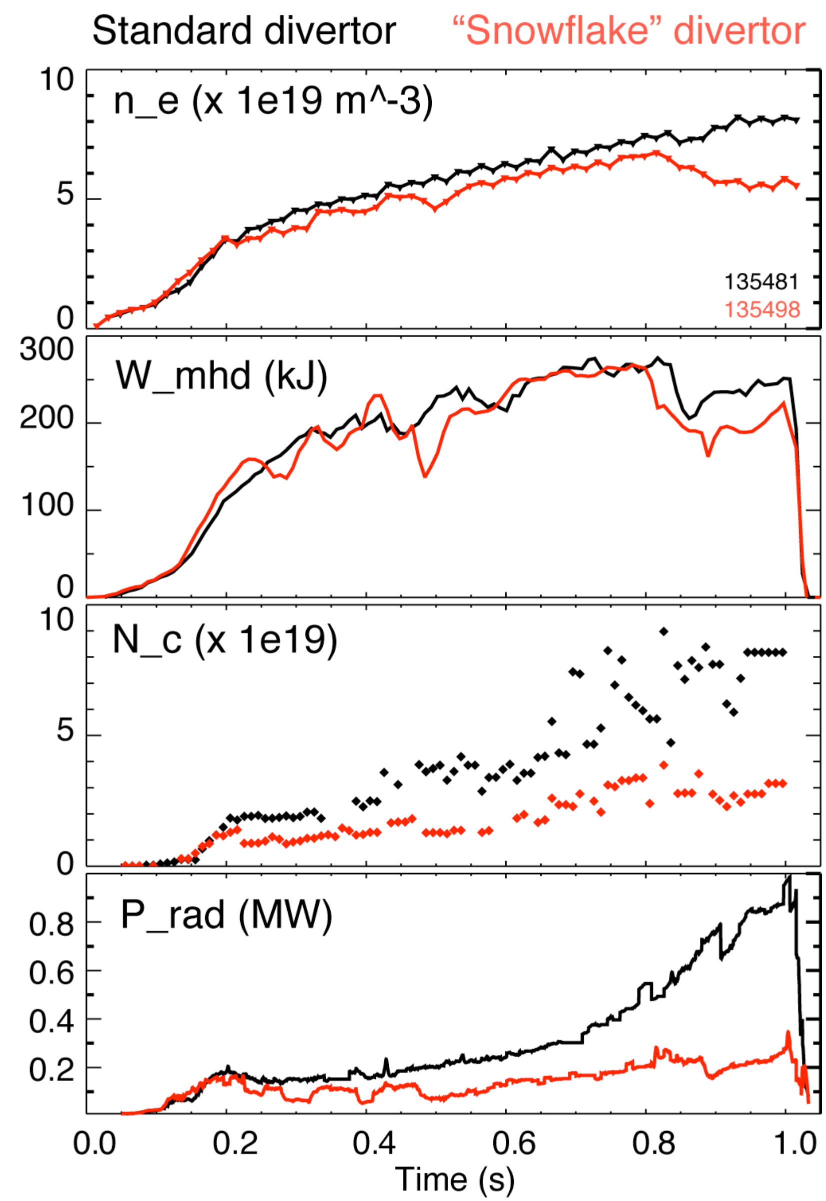


red-PDD, black - reference

Significant core n_C and P_{rad} reduction observed in snowflake divertor experiments

- Medium-δ 0.9 MA 4-6 MW NBI discharge (standard divertor, black)
- "Snowflake" divertor with detached outer strike point region (red)
- Used lithium at ~ 8-10 mg/min
- First detachment observation in NSTX without gas puffing





Use deuterium divertor injection to study effects on core impurity density

- In a discharge with gas puffing
  - T_e-dependent physical and chemical carbon sputtering rates are reduced
    - reduced impurity source ?
  - neutral pressure increased in SOL and divertor
    - preferentially decreased wall impurity source?
    - increased impurity compression in divertor due to D flow?
    - parallel momentum balance (viscosity), E_r, SOL flows (both drift and source) changed → change SOL radial impurity transport ?
    - n_0-dependent neoclassical convention in confined edge plasma?
    - collisional thermalization of fast ions?
- In lithium discharges inner divertor is attached (while it is detached in no-lithium discharges)
  - Inner divertor a significant carbon source?
- Generally ELM-free H-modes present a unique opportunity to study impurity sources and SOL impurity transport

Run plan focuses on developing a scenario with minimum divertor gas rate and no core impurity accumulation

- Use 8-12 mg/min LITER rate
- Use high-δ ELM-free 1 MA, 3-5 MW NBI fiducial with high P_{rad} and Z_{eff}
- Inject D_2 from Bay E divertor injector
  - Vary rate 30-150 Torr l /s (detachment observed at 150-200 Torr l /s)
  - Vary injection duration between 50-200 ms
  - Inject during flat-top, I_p ramp-up

- Measure carbon and P_{rad} profiles as function of gas injection
  - in core plasma, in lower / upper divertors, outer midplane and inner wall
  - infer carbon influx from inner, outer divertor, main chamber
- Connect with impurity transport and edge 2D modeling
- Connect with pedestal stability analysis
  - Reduced "ear" n_C and n_e may change edge pressure gradient and affect ELMs